

This invention relates generally to the field of telecommunications networks, and more particularly, to a protection method and system for equipment in a network element.

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Figure 1. The effect of the concentration of the  $\text{Cu}^{2+}$  ions on the  $\text{Cu}^{2+}$  adsorption capacity of the  $\text{Cu}^{2+}$  adsorbent. The concentration of the  $\text{Cu}^{2+}$  ions was 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19, 0.20, 0.21, 0.22, 0.23, 0.24, 0.25, 0.26, 0.27, 0.28, 0.29, 0.30, 0.31, 0.32, 0.33, 0.34, 0.35, 0.36, 0.37, 0.38, 0.39, 0.40, 0.41, 0.42, 0.43, 0.44, 0.45, 0.46, 0.47, 0.48, 0.49, 0.50, 0.51, 0.52, 0.53, 0.54, 0.55, 0.56, 0.57, 0.58, 0.59, 0.60, 0.61, 0.62, 0.63, 0.64, 0.65, 0.66, 0.67, 0.68, 0.69, 0.70, 0.71, 0.72, 0.73, 0.74, 0.75, 0.76, 0.77, 0.78, 0.79, 0.80, 0.81, 0.82, 0.83, 0.84, 0.85, 0.86, 0.87, 0.88, 0.89, 0.90, 0.91, 0.92, 0.93, 0.94, 0.95, 0.96, 0.97, 0.98, 0.99, 1.00, 1.01, 1.02, 1.03, 1.04, 1.05, 1.06, 1.07, 1.08, 1.09, 1.10, 1.11, 1.12, 1.13, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20, 1.21, 1.22, 1.23, 1.24, 1.25, 1.26, 1.27, 1.28, 1.29, 1.30, 1.31, 1.32, 1.33, 1.34, 1.35, 1.36, 1.37, 1.38, 1.39, 1.40, 1.41, 1.42, 1.43, 1.44, 1.45, 1.46, 1.47, 1.48, 1.49, 1.50, 1.51, 1.52, 1.53, 1.54, 1.55, 1.56, 1.57, 1.58, 1.59, 1.60, 1.61, 1.62, 1.63, 1.64, 1.65, 1.66, 1.67, 1.68, 1.69, 1.70, 1.71, 1.72, 1.73, 1.74, 1.75, 1.76, 1.77, 1.78, 1.79, 1.80, 1.81, 1.82, 1.83, 1.84, 1.85, 1.86, 1.87, 1.88, 1.89, 1.90, 1.91, 1.92, 1.93, 1.94, 1.95, 1.96, 1.97, 1.98, 1.99, 2.00, 2.01, 2.02, 2.03, 2.04, 2.05, 2.06, 2.07, 2.08, 2.09, 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.21, 2.22, 2.23, 2.24, 2.25, 2.26, 2.27, 2.28, 2.29, 2.30, 2.31, 2.32, 2.33, 2.34, 2.35, 2.36, 2.37, 2.38, 2.39, 2.40, 2.41, 2.42, 2.43, 2.44, 2.45, 2.46, 2.47, 2.48, 2.49, 2.50, 2.51, 2.52, 2.53, 2.54, 2.55, 2.56, 2.57, 2.58, 2.59, 2.60, 2.61, 2.62, 2.63, 2.64, 2.65, 2.66, 2.67, 2.68, 2.69, 2.70, 2.71, 2.72, 2.73, 2.74, 2.75, 2.76, 2.77, 2.78, 2.79, 2.80, 2.81, 2.82, 2.83, 2.84, 2.85, 2.86, 2.87, 2.88, 2.89, 2.90, 2.91, 2.92, 2.93, 2.94, 2.95, 2.96, 2.97, 2.98, 2.99, 3.00, 3.01, 3.02, 3.03, 3.04, 3.05, 3.06, 3.07, 3.08, 3.09, 3.10, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19, 3.20, 3.21, 3.22, 3.23, 3.24, 3.25, 3.26, 3.27, 3.28, 3.29, 3.30, 3.31, 3.32, 3.33, 3.34, 3.35, 3.36, 3.37, 3.38, 3.39, 3.40, 3.41, 3.42, 3.43, 3.44, 3.45, 3.46, 3.47, 3.48, 3.49, 3.50, 3.51, 3.52, 3.53, 3.54, 3.55, 3.56, 3.57, 3.58, 3.59, 3.60, 3.61, 3.62, 3.63, 3.64, 3.65, 3.66, 3.67, 3.68, 3.69, 3.70, 3.71, 3.72, 3.73, 3.74, 3.75, 3.76, 3.77, 3.78, 3.79, 3.80, 3.81, 3.82, 3.83, 3.84, 3.85, 3.86, 3.87, 3.88, 3.89, 3.90, 3.91, 3.92, 3.93, 3.94, 3.95, 3.96, 3.97, 3.98, 3.99, 4.00, 4.01, 4.02, 4.03, 4.04, 4.05, 4.06, 4.07, 4.08, 4.09, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.17, 4.18, 4.19, 4.20, 4.21, 4.22, 4.23, 4.24, 4.25, 4.26, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33, 4.34, 4.35, 4.36, 4.37, 4.38, 4.39, 4.40, 4.41, 4.42, 4.43, 4.44, 4.45, 4.46, 4.47, 4.48, 4.49, 4.50, 4.51, 4.52, 4.53, 4.54, 4.55, 4.56, 4.57, 4.58, 4.59, 4.60, 4.61, 4.62, 4.63, 4.64, 4.65, 4.66, 4.67, 4.68, 4.69, 4.70, 4.71, 4.72, 4.73, 4.74, 4.75, 4.76, 4.77, 4.78, 4.79, 4.80, 4.81, 4.82, 4.83, 4.84, 4.85, 4.86, 4.87, 4.88, 4.89, 4.90, 4.91, 4.92, 4.93, 4.94, 4.95, 4.96, 4.97, 4.98, 4.99, 5.00, 5.01, 5.02, 5.03, 5.04, 5.05, 5.06, 5.07, 5.08, 5.09, 5.10, 5.11, 5.12, 5.13, 5.14, 5.15, 5.16, 5.17, 5.18, 5.19, 5.20, 5.21, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30, 5.31, 5.32, 5.33, 5.34, 5.35, 5.36, 5.37, 5.38, 5.39, 5.40, 5.41, 5.42, 5.43, 5.44, 5.45, 5.46, 5.47, 5.48, 5.49, 5.50, 5.51, 5.52, 5.53, 5.54, 5.55, 5.56, 5.57, 5.58, 5.59, 5.60, 5.61, 5.62, 5.63, 5.64, 5.65, 5.66, 5.67, 5.68, 5.69, 5.70, 5.71, 5.72, 5.73, 5.74, 5.75, 5.76, 5.77, 5.78, 5.79, 5.80, 5.81, 5.82, 5.83, 5.84, 5.85, 5.86, 5.87, 5.88, 5.89, 5.90, 5.91, 5.92, 5.93, 5.94, 5.95, 5.96, 5.97, 5.98, 5.99, 6.00, 6.01, 6.02, 6.03, 6.04, 6.05, 6.06, 6.07, 6.08, 6.09, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.17, 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29, 6.30, 6.31, 6.32, 6.33, 6.34, 6.35, 6.36, 6.37, 6.38, 6.39, 6.40, 6.41, 6.42, 6.43, 6.44, 6.45, 6.46, 6.47, 6.48, 6.49, 6.50, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, 6.57, 6.58, 6.59, 6.60, 6.61, 6.62, 6.63, 6.64, 6.65, 6.66, 6.67, 6.68, 6.69

BACKGROUND OF THE INVENTION

Telecommunications networks transmit voice and other data between end users. The networks include switch and management nodes for processing and routing traffic in the network and links between the nodes for carrying the traffic. The links are circuit switched or packet switched wireline links, wireless links, or a combination of link types. End users communicate data over telephones, computers, personal digital assistants (PDA) and other similar devices.

Telecommunication nodes include redundant equipment and are connected to redundant to provide fault tolerance and allow continued operation in the event of equipment or link failure. Typically, each transmission link as well as line or switch cards of the nodes are backed up by corresponding links and cards to ensure that all traffic is protected at all parts of the network. This 1+1 protection, however, is expensive to maintain as fully half of the networks capacity is maintained in reserved for protection switching and is not used during normal operation of the network.

To increase network efficiency, 1:N protection architectures have been developed and deployed in telecommunications nodes. In this architecture, a number (N) of cards or other items are protected by a single item. Thus full protection is provided for any single failure. Multiple concurrent failures, however, cannot be completely protected. In the event of multiple concurrent failures, equipment is typically protected based on a failure request priority. Within the priorities, equipment is protected on a first failed basis, which can lead to less important equipment being



SUMMARY OF THE INVENTION

The present invention provides a protection method and system for equipment in a network element of a telecommunications network that significantly reduce or eliminate elements problems and disadvantages associated with previous systems and methods. In particular, the present invention prioritizes protection for failed equipment based on both protection request type and failed equipment type.

10 In accordance with one embodiment of the present invention, a method and system for providing protection switching for equipment in a network element includes receiving a protection request for an equipment item. A priority of the request and a priority of the equipment item is evaluated relative to all other outstanding protection requests for other equipment items in a protection group with the equipment item. A highest priority protection request for a highest priority equipment item is performed.

20 More specifically, in accordance with a particular embodiment of the present invention, the equipment items in the protection group comprise line interface cards. The line interface cards may each comprise a plurality of DS-1 or other single user connections. The protection request may be an activation request or a deactivation request for an equipment item.

30 Technical advantages of the present invention include providing an improved method and system for protecting equipment in a network element. In a particular embodiment, a plurality of equipment items are protected by a single item with protection priority being provided based on protection request type and failed equipment type. Accordingly, during multiple concurrent

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BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, wherein like reference numerals  
5 represent like parts, in which:

FIGURE 1 is a block diagram illustrating a network element for a telecommunications system in accordance with one embodiment of the present invention;

10 FIGURE 2 is a block diagram illustrating details of the finite state machine of FIGURE 1 in accordance with one embodiment of the present invention;

FIGURE 3 is a block diagram illustrating details of the state table of FIGURE 1 in accordance with one  
15 embodiment of the present invention;

FIGURES 4 is a functional diagram illustrating input and output of the finite state machine of FIGURE 1 in accordance with one embodiment of the present invention;

FIGURE 5 is a flow diagram illustrating a method for  
20 processing protection request in accordance with one embodiment of the present invention; and

FIGURE 6 is a flow diagram illustrating a method for evaluating protection request for the method of FIGURE 5 based on protection request type and equipment type in  
25 accordance with one embodiment with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates a network element 10 for a telecommunications network in accordance with one embodiment of the present invention. The telecommunications network transmits voice, data, or other suitable types of information, and/or a combination of types of information between end users. The telecommunications network may include a public network such as the Internet and the public switched telephone network (PSTN) as well as private networks such as wide area networks (WAN) and local area networks (LAN).

The telecommunications network includes a plurality of network elements interconnected by transmission links. The network elements may comprise a switch, router, add/drop multiplexer, access device or other suitable device capable of directing traffic in the telecommunications network. The transmission links provide the physical interface between the network elements. The physical interfaces are defined by bandwidth of the connecting transmission links which may be DS-1 lines, DS-3 lines, OC-3 lines, OC-12 lines or other suitable bandwidths. Transmission links may comprise optical fiber, cable, twisted wire, or other suitable wireline or wireless links capable of transporting traffic between network elements.

Referring to FIGURE 1, the network element 10 is illustrated as a add/drop multiplexer 12 including a service complex 20, a transport complex 22, a switch complex 24, a management complex 26, and a synchronization complex 28. The complexes 20, 22, 24, 26 and 28 are interconnected by one or more buses or backplanes in the add/drop multiplexer 12.

15       The working tributary cards 32 each receive customer  
input/output (I/O) and perform conversions necessary for  
processing by the switch complex 24. In one embodiment,  
each tributary card 34 is a DS-1 card and receives a  
plurality of DS-1 connections 36. It will be understood  
20 that the protection groups 30 may comprise a set of other  
suitable equipment items and/or the tributary cards 32  
may receive other suitable types of single user  
connections and/or other suitable types of aggregated  
traffic connections and/or a combination of connection  
25 types.

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embodiment, the line cards 42 and 44 also perform overhead construction and insertion.

The switch complex 24 comprises one or more switch fabrics for switching traffic between the service complex 20 and the transport complex 22 and between the cards within the service and transport complexes 20 and 22. In a particular embodiment, the switch complex 24 includes synchronous optical network (SONET) and asynchronous transfer mode (ATM) switch fabrics.

The management complex 26 monitors and controls the status of the service, transport, switch and synchronization complexes 20, 22, 24 and 28. The management complex 26 also provides network management functions, controls protection switching, and maintains provision databases for the add/drop multiplexer 12. The synchronization complex 28 synchronizes the service, transport, switch and management complexes 20, 22, 24 and 26 by providing a stable traceable reference clock.

In one embodiment, the management complex 26 includes a user interface 50 and a protection controller 52. The user interface 50 communicates with network operators to allow local and remote control and provisioning of the add/drop multiplexer 12 by the network operator and to respond to queries for information about the status of the add/drop multiplexer 12. In a particular embodiment, the user interface 50 translates requests received from a network management station (NMS) to a native format of the add/drop multiplexer 12 and forwards the requests to the appropriate complex and/or controller for processing. In this embodiment, the user interface 50 also converts responses and/or messages from the add/drop multiplexer

12 to the native language of the NMS for reporting to the network operator.

5 The protection controller 52 receives and processes protection requests from the network operator received through the user interface 50 and from the hardware including the service, transport and switch complexes 20, 22 and 24. In response to failure of an equipment item, the protection activation request is automatically generated locally within a complex and forwarded to the  
10 protection controller 52, an alarm forwarded to the protection controller 52 for automatic generation of the protection requests or otherwise suitably generated based on the state of the hardware. Protection requests comprise activation requests for activation of protected  
15 equipment in case of failed or out of service working equipment or deactivation requests for deactivation of protection equipment in response to return to service of working equipment.

20 In one embodiment, the protection controller 52 includes a plurality of protection group managers 54. Each protection group manager 54 controls protection requests for a corresponding protection group 30 and/or 40 on the service and transport complexes 20 and 22. The protection group managers 54 each include a finite state  
25 machine 60 and a state memory 62. As used herein, the term each means everyone of at least a subset of the identified items. The finite state machine 60 controls activation of protection request for protection switching based on the state of cards 32 and 34 in the protection  
30 group 30 and/or the state of cards 42 and 44 in protection group 44. The state memory 62 stores the state of cards 32 and 34 in the protection group 30

and/or the state of cards 42 and 44 in the protection group 40.

The complexes, cards, protection controller 52 and other elements and equipment of the add/drop multiplexer 12 comprise logic stored as software encoded on a computer-readable medium for execution by a general purpose processor or logic stored as instructions in an application specific integrated circuit (ASIC), field programmable gate array (FPGA) or other suitable medium, which may comprise one or more media devices and types. It will be understood that the protection controller 52 may be implemented entirely on the management complex 26 or its functionality distributed within the add/drop multiplexer 12.

FIGURE 2 illustrates details of the tributary cards 32 the finite state machine 60 for 1:N protection of the tributary cards 32 in accordance with one embodiment of the present invention. In this embodiment, the finite state machine 60 includes rules 80 specifying the priority of requests and the priority of cards or other suitable equipment items to be protected in the protection group 30. Thus, the finite state machine 60 may be customized for each protection group 30 and/or for protection groups of different equipment types.

Referring to FIGURE 2, the rules 80 includes a protection requests hierarchy 82 and an equipment protection hierarchy 84. The requests hierarchy 82 includes an ascending hierarchy of request. In a particular embodiment, the request hierarchy 82 includes a highest priority of failure of protection, followed in order by lockout of protection, forced switch, failure of working and manual switch. In this embodiment, failure of protection is a failure of the protection card 34,

lockout of protection is a lockout by the network operator of the protection card 34, forced switch is a high priority manual switch by the network operator, failure of a working is a failure of a working tributary card 32 and manual switch is a low priority manual switch by the network operator. It will be understood that other or different types of requests may be included within the requests hierarchy 82 in that the requests types may be otherwise suitably prioritized.

10       The equipment hierarchy 84 defines the priority of the working tributary cards 32 in the protection group 30. In a particular embodiment, the tributary cards are prioritized based on a card number such as card 1 to card 6, channel reference number or other suitable reference or identifier. In this embodiment, the tributary cards 32 may be provisioned in order based on their priority. Alternatively, the tributary cards 32 may be provisioned and the protection order later defined in the equipment hierarchy 84.

20       FIGURE 3 illustrates the state memory 62 in accordance with one embodiment of the present invention. In this embodiment, the states of the working and protect tributary cards 32 and 34 are stored in a table 90. The table 90 includes a column for each working tributary card 32 and the protect card 34 and a row for each type of protection activity. For the finite state machine 60 of FIGURE 2, the protection activities are forced, lockout, manual and automatic. A forced activity is a high priority network operator initiated activity, a manual activity is a low priority network operation initiated activity, an automatic activity is a an activity generated automatically in response to a

hardware or other failure or alarm and a lockout activity is an activity preventing use of a card.

Referring to FIGURE 3, a bit is set in each entry 92 of the table 90 indicating the status of the corresponding card for the corresponding activity. In a particular embodiment, the bits are set to zero in the absence of the defined activity and set to 1 during the occurrence of the activity. It will be understood that the states of the working and protect cards 32 and 34 in the protection group 30 may be otherwise suitably stored in the protection controller 52 without departing from the scope of the present invention.

FIGURE 4 is a functional diagram illustrating input to and output from the finite state machine 60 in accordance with one embodiment of the present invention. In this embodiment, a network operator or other user 120 initiates user protection requests 122 for any of the working tributary card 32 and the protect card 34. The operator requests are received by the user interface 50, translated and passed to the protection controller 52 for evaluation.

The working or protect tributary cards 32 or 34 or other hardware 130 each generate automatic requests 132 in response to card failures, alarm conditions and/or other suitable events and/or conditions of the hardware 130. As used herein, the phrase in response to means performing the identified action directly or indirectly following the identified event. Thus, the action may occur immediately or substantially immediately upon the occurrence of the event or after another necessary or intervening event.

The finite state machine 60 receives the operator requests 122 and the automatic requests 132 and evaluates

the requests based on priority of the requests and priority of the equipment for which the requests is made to determine protection activity 140. The protection activity 140 is output by the finite state machine 60 to the hardware 130 for performance by the hardware. In this way, the protection activity is determined based on all of the operator and automatic request 122 and 132 to provide optimized protection for any state of the protection group 30.

FIGURE 5 illustrates a method for processing protection request for an 1:N protection group in accordance with one embodiment of the present invention. The method begins at step 150 in which a protection requests is generated. The requests may be generated by a network operator at a NMS or by hardware 130 in response to a failure, alarm condition or other suitable condition of the hardware.

Preceding to step 152, the requests is communicated to the protection controller 52. For operator, or user, initiative request, the request may be translated by the user interface 50 before being passed to the protection controller 52. Similarly, hardware initiated requests may be translated prior to transmission to the protection controller 52 if not in the native language of the controller 52.

At step 154, the request is evaluated based on a priority of the request and a priority of the equipment for which the request is generated. As described in more detail below, the request is evaluated by comparing the priority of the request and of the equipment to the priority of all other requests for the same or other equipment in the protection group 30. Next, at decisional step 156, the requests is activated if the

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At decisional step 206, the finite state machine 60 determines whether there are competing protection request  
5 for use of the protect card 32. If there is only one outstanding request, the No branch of decisional step 206 leads to step 208 in which the lone outstanding request is performed. Upon performance of the protection request, step 208 returns to monitoring state 200 such  
10 that protection status may be reevaluated in response to any further requests.

Next, at decisional step 212, the finite state machine 60 determines whether there are multiple requests at the highest priority. If only a single requests is of the highest priority, the No branch of decisional step 212 leads to step 214. At step 214, the selected highest priority protection requests is performed. Step 214 returns to monitor state 200 in which the finite state machine 60 continues to monitor the protection group 30 for further request activity.

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Although the present invention has been described  
20 with several embodiments, various changes and  
modifications may be suggested to one skilled in the art.  
It is intended that the present invention encompasses  
such changes and modifications that fall within the scope  
of the appended claims and their equivalents.